Good Current Practices for Managing Nanomaterials

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Charles L. Geraci, Ph.D., CIH

Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

CDC Workplace Safety and Health

The findings and conclusions in this presentation have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy

NIOSH

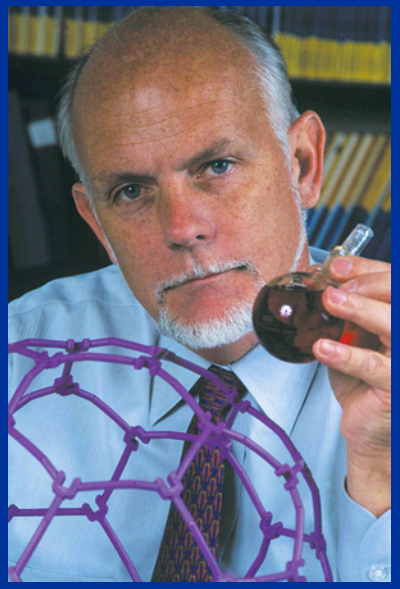
Overview

- Nanotechnology: A 10-second refresher
- What are the risks of “Nanomaterials”
- Key material management issues and challenges
- Good risk management principles apply to nanomaterials

Many thanks to Mark Methner, Laura Hodson, Donna Heidel, and Bob Sussman

Nanotechnology: The Fast Definition

- Manipulating matter at the atomic level
- Creating materials that have new and unique properties because of their size.
- Creating structure and function in the nanometer range



Richard Smalley
Nobel Prize Winner, Chemistry (1996)

Nanotechnology:

"The art and science of building stuff that does stuff at the nanometer scale"

AKA: Material science, one molecule at a time.
(1943 - 2005)

"Just about anything can be made faster, stronger, smarter, smaller, better, etc., using nanomaterial science"

So, unless you've been living with this guy,

you realize that nanotechnology is poised to impact many arenas.

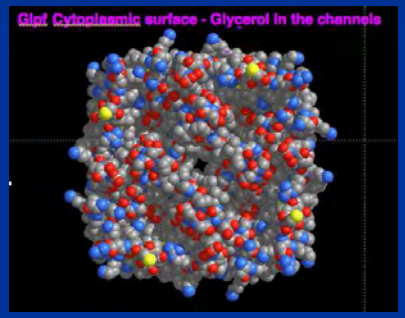
Nanotechnology and Occupational Health

- Nanomaterials are purposely engineered for their unique, size-dependent properties and behavior.
- Do these new 'nano' materials present new safety and health risks?
- How can the benefits of nanotechnology be realized while proactively minimizing the potential risk?

The Focus: Free Engineered Nanoscale Particulate Matter–"Nanoparticles"

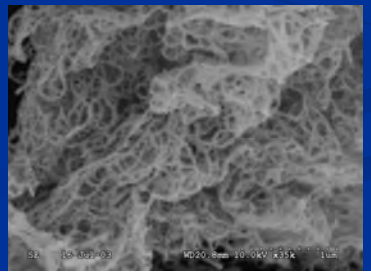
- Not firmly attached to a surface
- Not part of a bigger item (e.g., microchip, cell wall)
- Can result in exposure via inhalation, skin absorption or Ingestion

Issue for inhalation: agglomerated ENP has the activity of the primary ENP



Nanoparticles are not new

Natural	Anthropogenic	
	Incidental	Engineered
Forest Fires	Combustion engines	Controlled size and shape
Volcanoes	Incinerators	Semiconductors, carbon
Viruses	Jet engines	Metal oxides, polymers
Gas-to-particles	Welding fumes	Nanospheres, -wires, needles, -tubes, -shells, -rings, -platelets



Where is it?

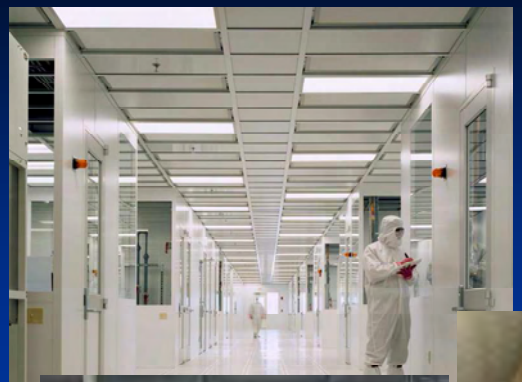
Current Uses and Applications of Nanotechnology

Agriculture	Pesticides and fertilizers
Automotive	composites, epoxies, films
Biomedical	diagnostics, drug delivery
Chemical	catalysts, polymer films, coatings
Electronics	catalysts, polymer films, coatings, fiber optics
Energy	catalysts, lithium batteries, fuel additives
Environmental	sensors, catalysts
Food	additives, packaging materials, antimicrobial
Household	antimicrobials, cleaners, coatings, appliances
Personal Care	cosmetics, sunscreens, hair/skin products
Sports	composites for bats and golf clubs, shoes
Textiles	water/stain resistance, wrinkle-free, fire resistance

Range of Possibilities Encountered

- Laboratory
  - Discovery, Synthesis
  - Scale Up
- Pilot Scale
  - Trial productions
  - Small batch processes
- Production
  - Continuous or batch
  - Custom formulation or treatment
- Incorporation
  - Small scale trials
  - High volume production of nano-enabled products

The good practice opportunities of Nanotechnology







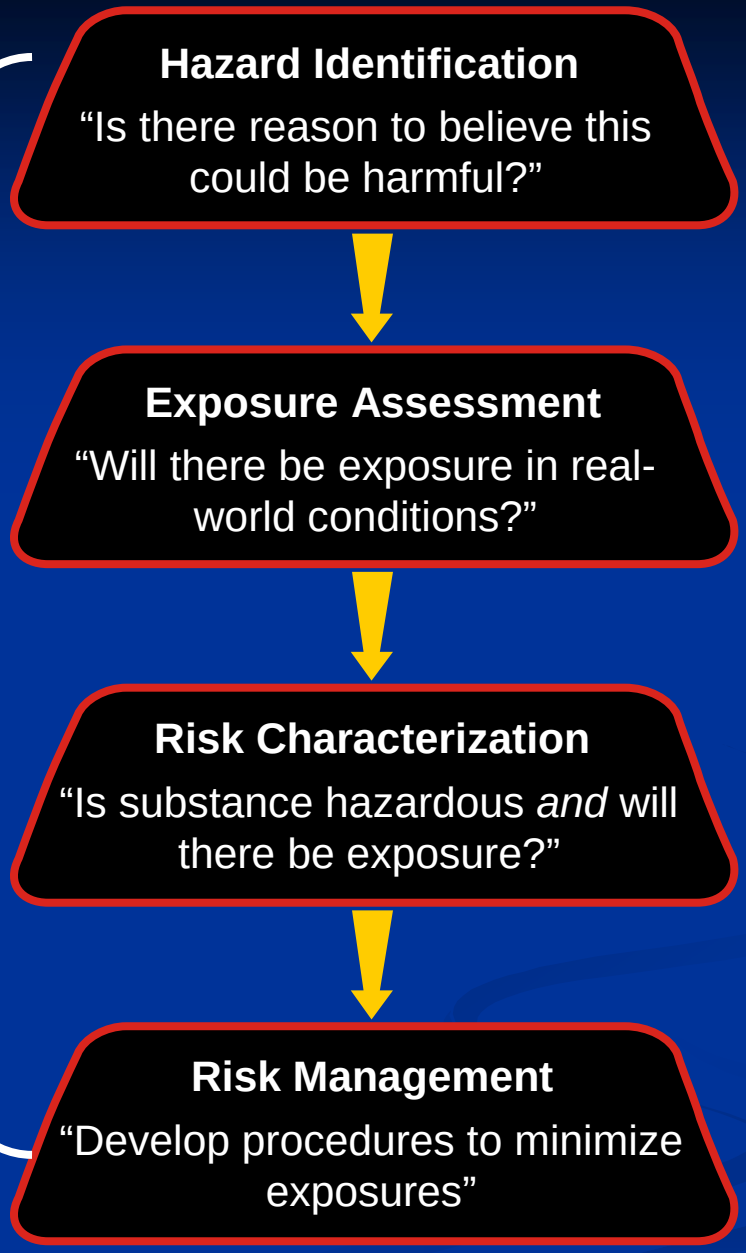


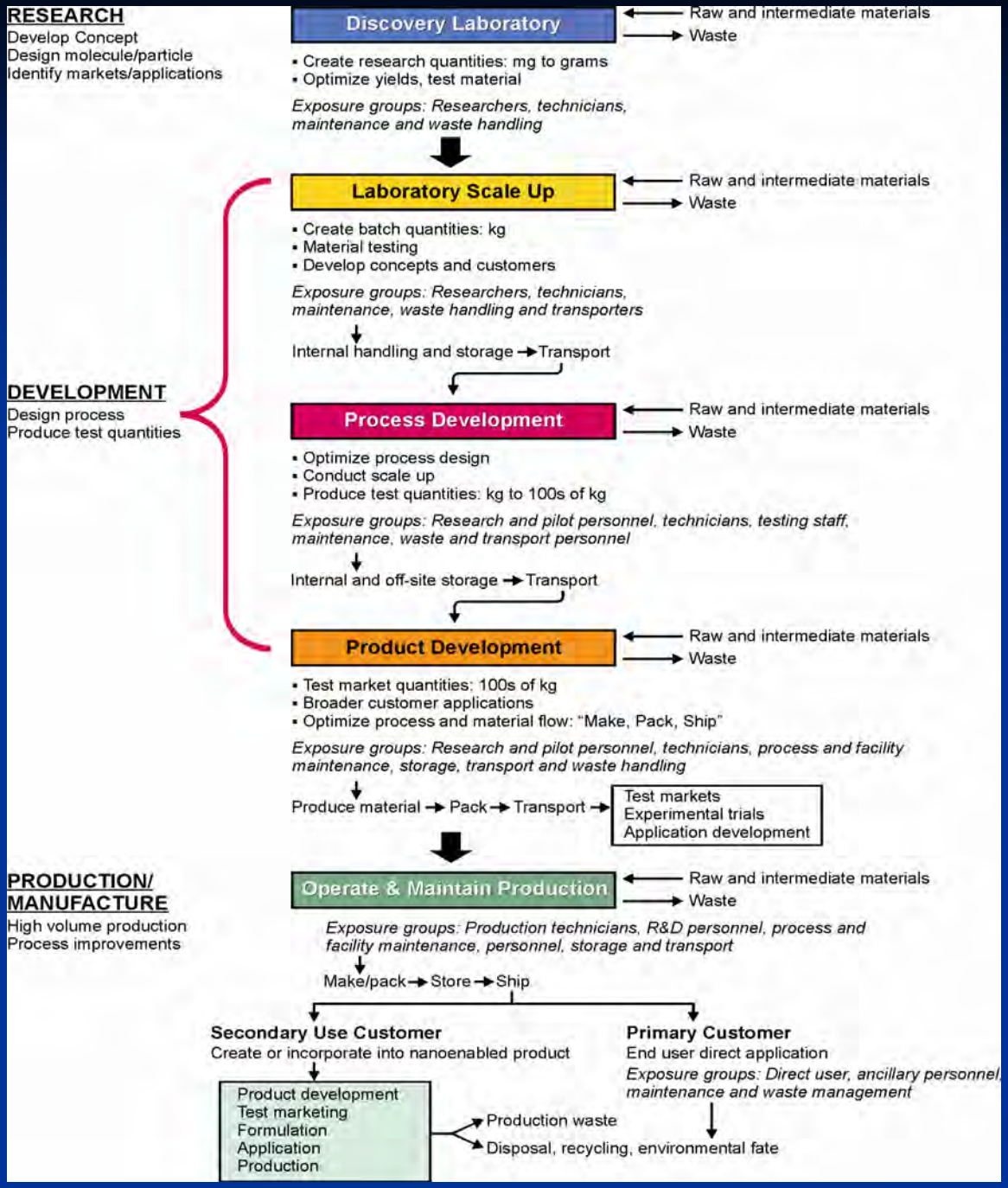
Key Elements of Risk Management

Are they hazardous?

Can they be measured?

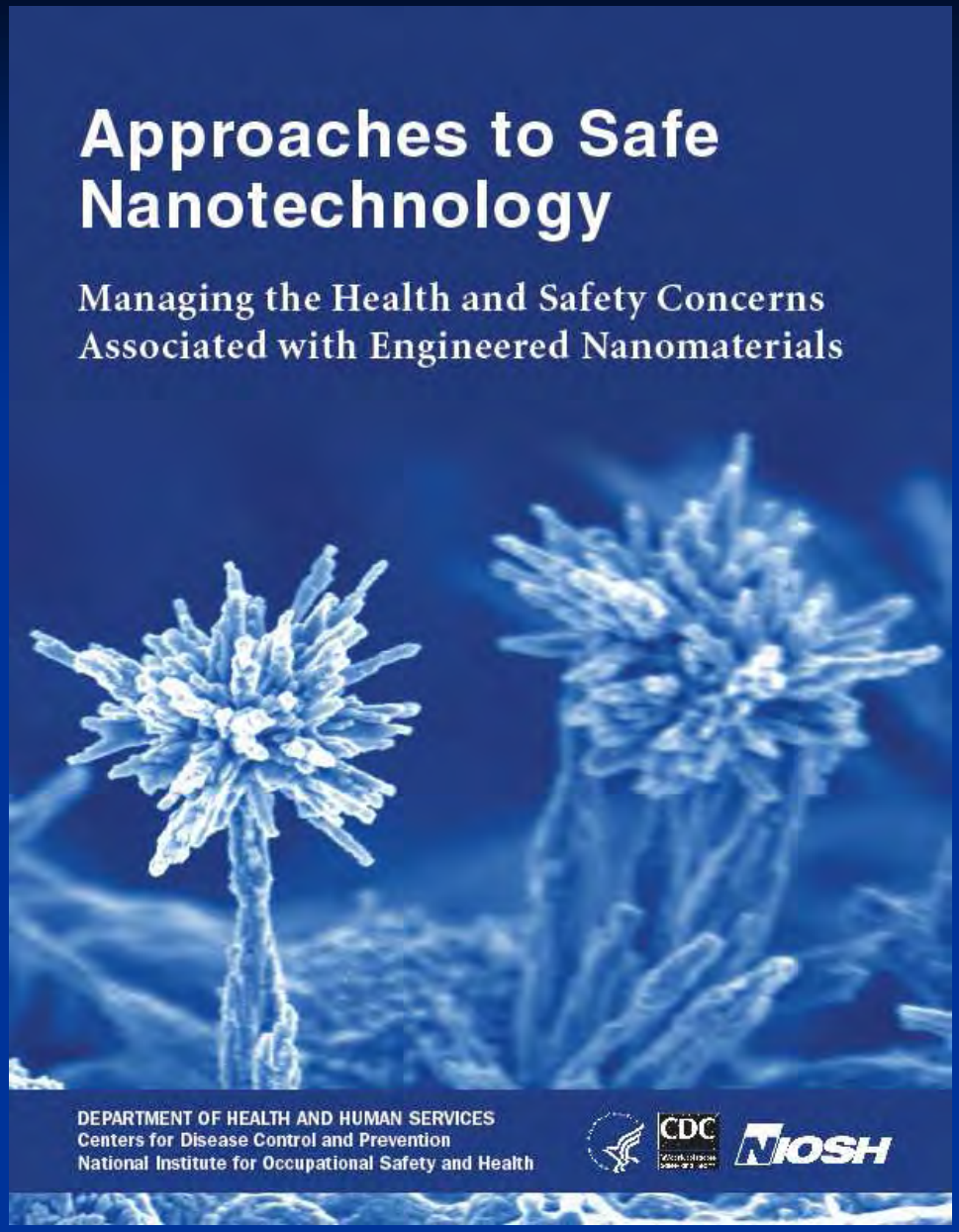
Can they be controlled?





The 'simple' life cycle view of nanomaterials in the workplace.

Where do I start?



Basic Guidance from NIOSH

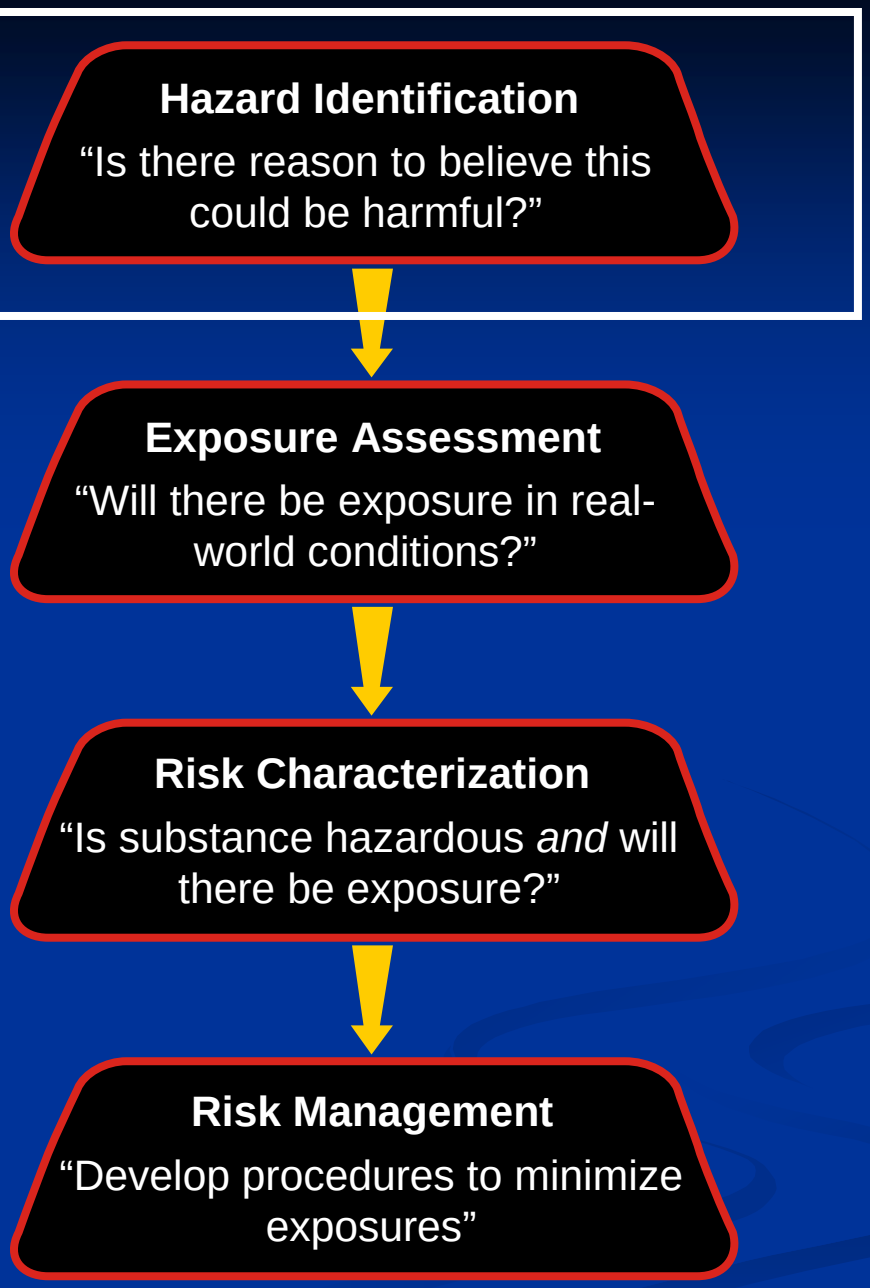
- **Updated and reissued in 2009**
- **Based on direct experience and applied research results**
- **Updated as new information is developed**
- **A starting point for building a responsible nanomaterial management program**

www.cdc.gov/niosh/topics/nanotech

Key Elements of Risk Management

Hazard

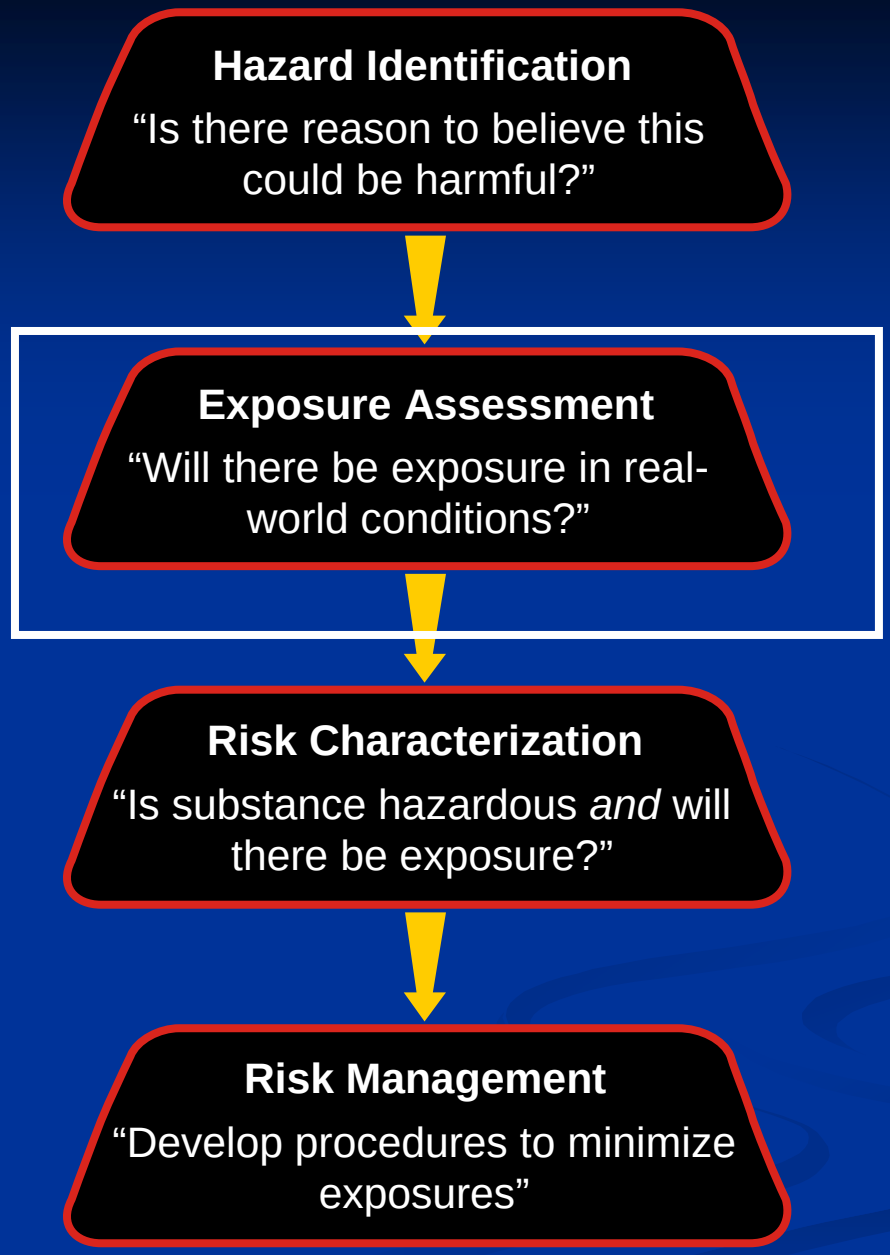
Nanotoxicology
What do we know?
Are there 'trends'?



Key Elements of Risk Management

Exposure →

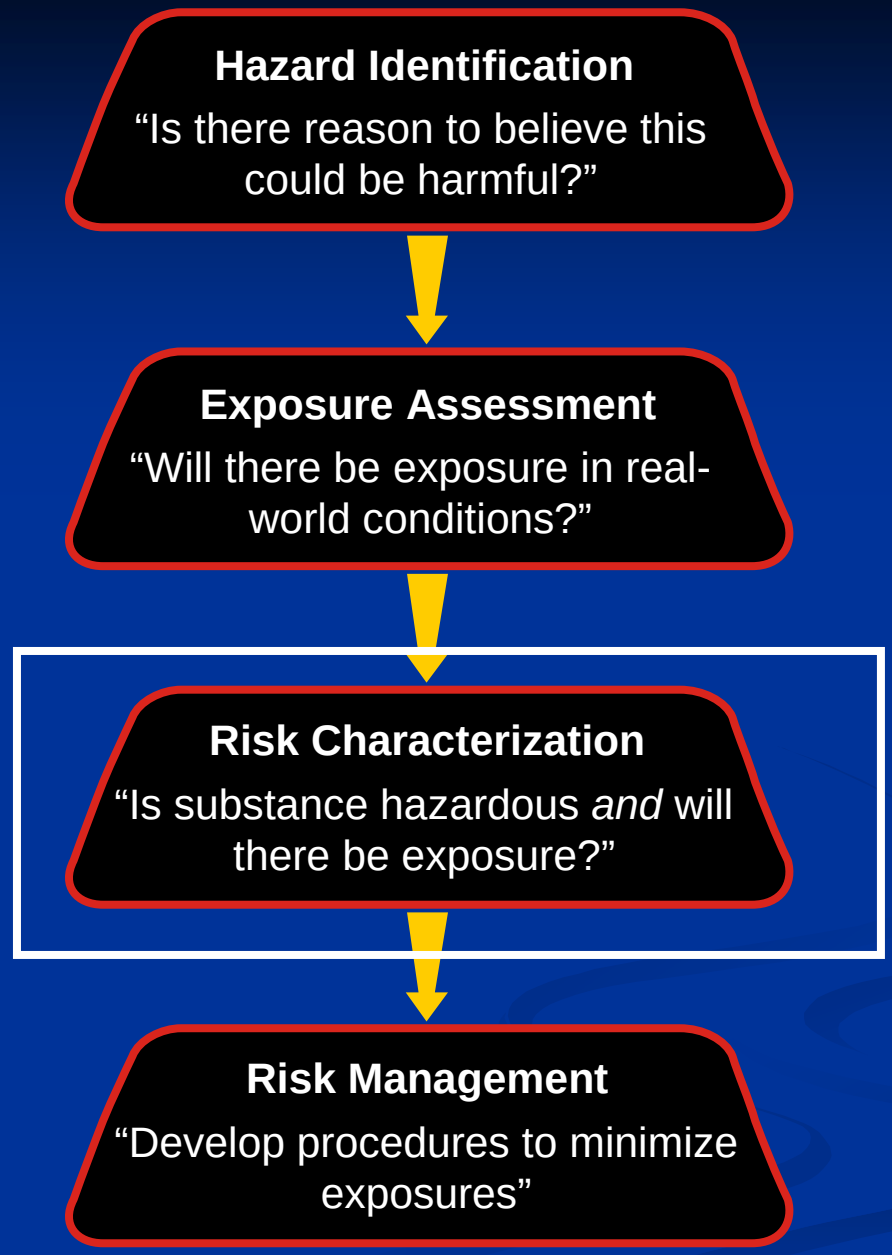
Can it be measured?
Where is it occurring?
Metric?



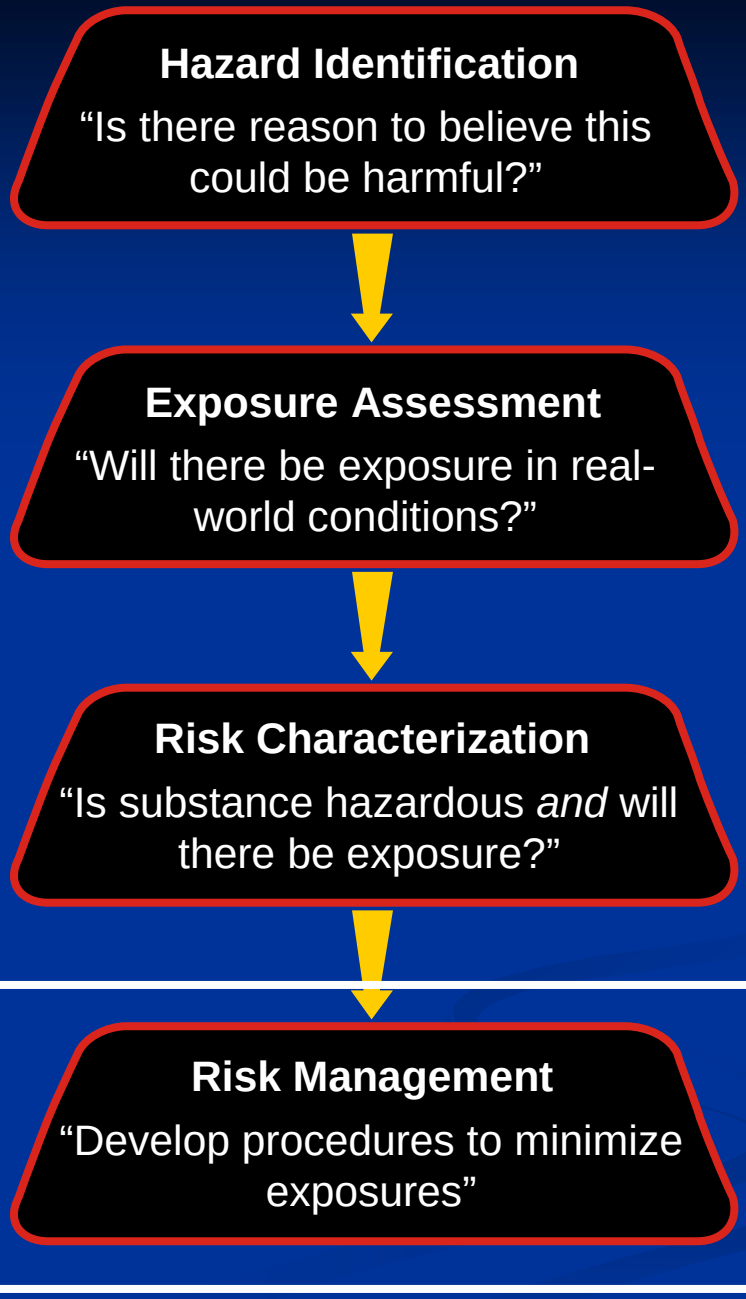
Key Elements of Risk Management

Risk

Hazard x Exposure.



Key Elements of Risk Management



Controls

What works?
What has been used?
What can be reapplied?

Framing the Hazard Picture

Based on what is known, how would we describe the hazard and the control needed?

More active than 'bulk form' ⇒ Next level up

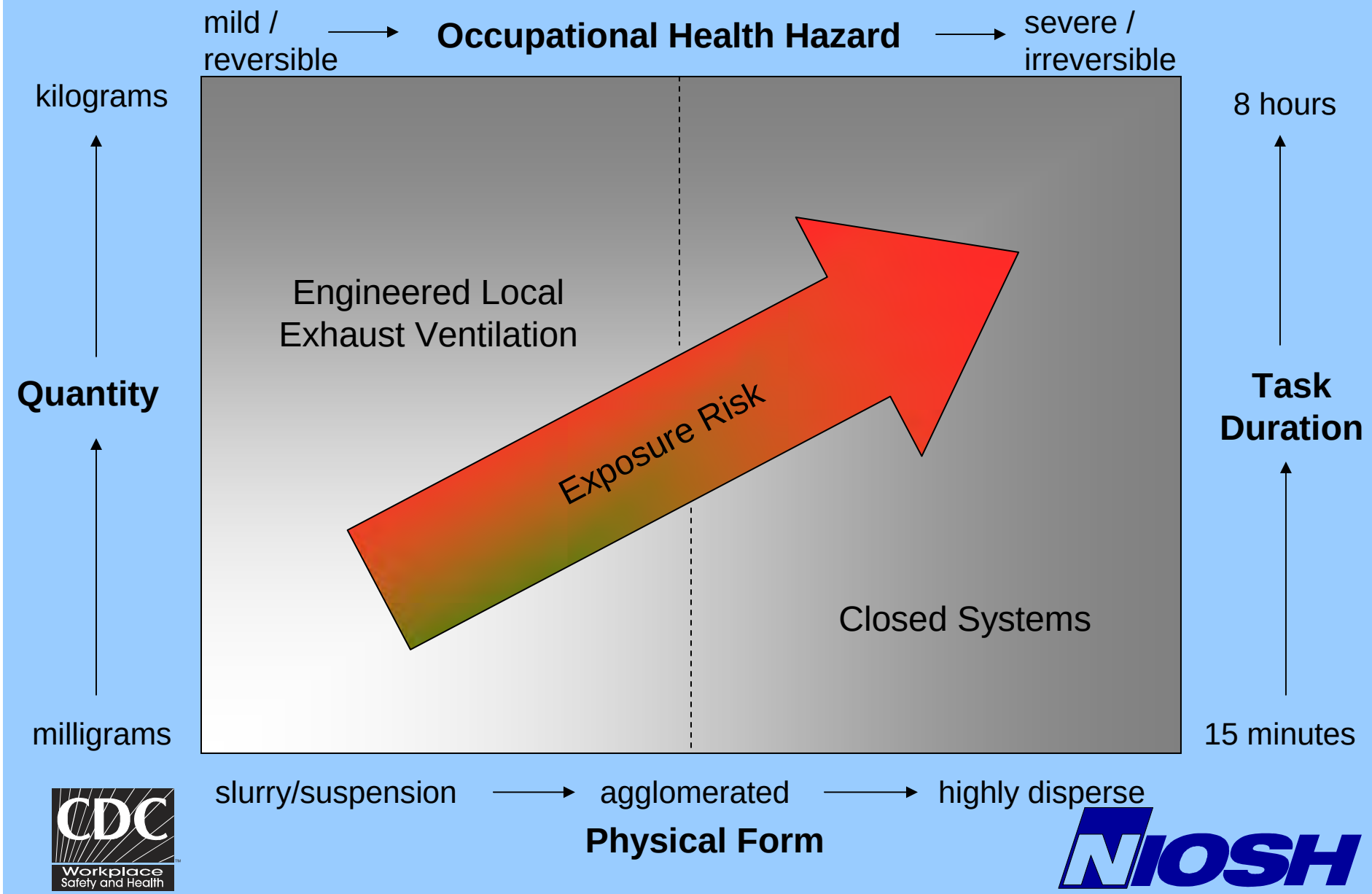
CNTs more active than TiO2 ⇒ Different controls

Is this how the hazard picture is shaping up?

Clays TiO2 Metal oxides Metals CNT Other ENP?

Less → More

Factors Influencing Control Selection



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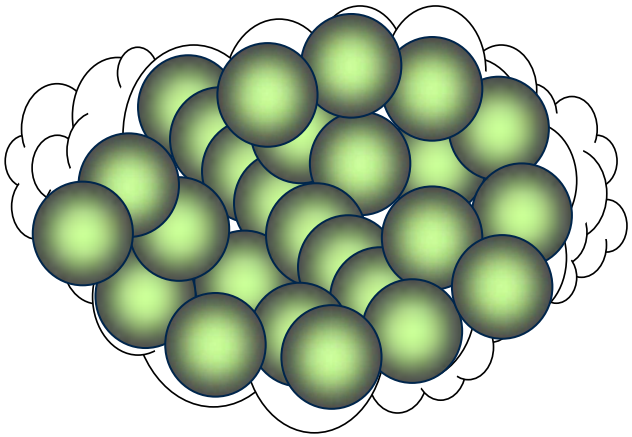
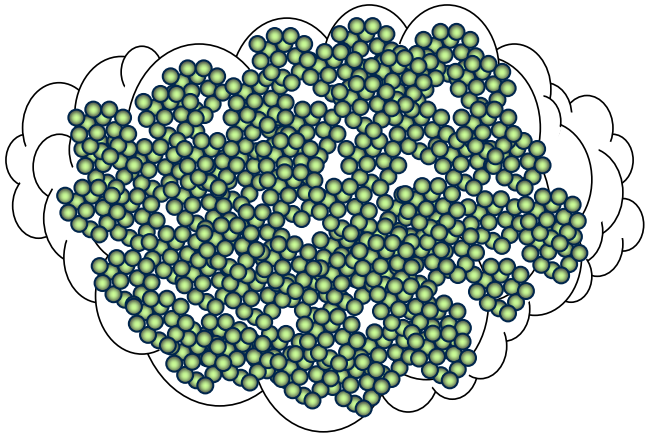
The ten-second control technology test for nanomaterials

Does one of these materials present a greater control and containment challenge?

Bulk Material

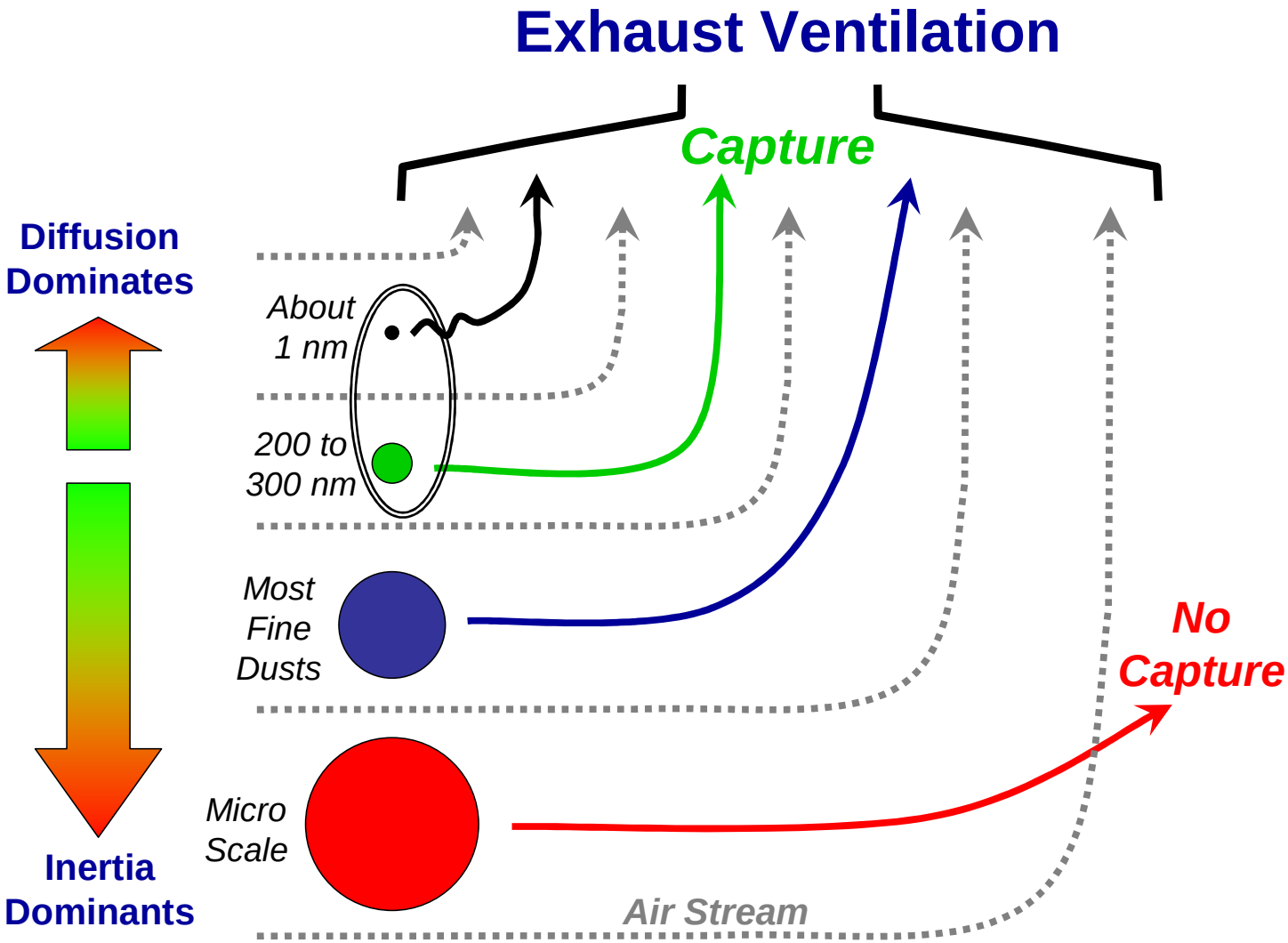


Nano Sized Particles



Same mass of material in an aerosol!

Initial Thinking: Conventional Controls Should Work



This is good and bad news: mobility is a key consideration

Borrow from the “Pharma Book”

Traditional Engineering Controls

- Ventilation
  - engineered local exhaust
    - at emissions points
    - effective to 100 µg/m³
  - laminar flow (hoods)
    - may be effective between 50 to 100 µg/m³
  - directionalized laminar flow (booths)
    - may be effective to 50 µg/m³ for less dusty operations
- Other
  - enclosures of specific parts and containers
  - vacuum transfer

Control Performance Examples*

Control Technology	Historical Performance
• Open handling with engineered local exhaust ventilation	< 1000 μg/m^3
• Directional laminar flow with LEV and Vacuum conveying	10 μg/m^3 – 1000 μg/m^3
• Closed systems	1- 10 μg/m^3
• High-containment	< 1 μg/m^3

Examples

**For handling bulk fine powders. Base control selection on factors that influence exposure risk*

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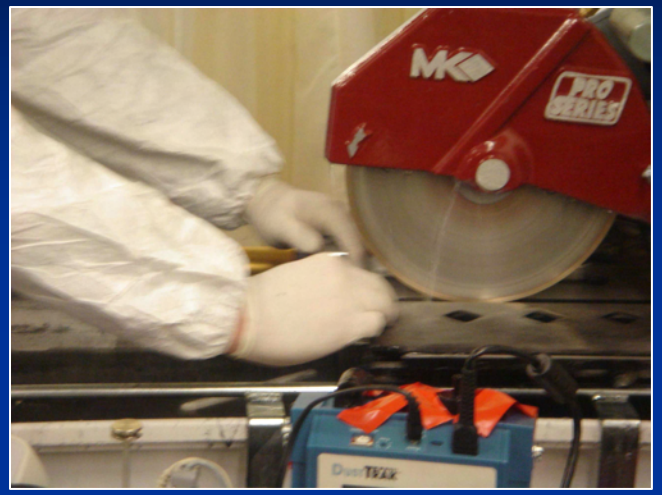
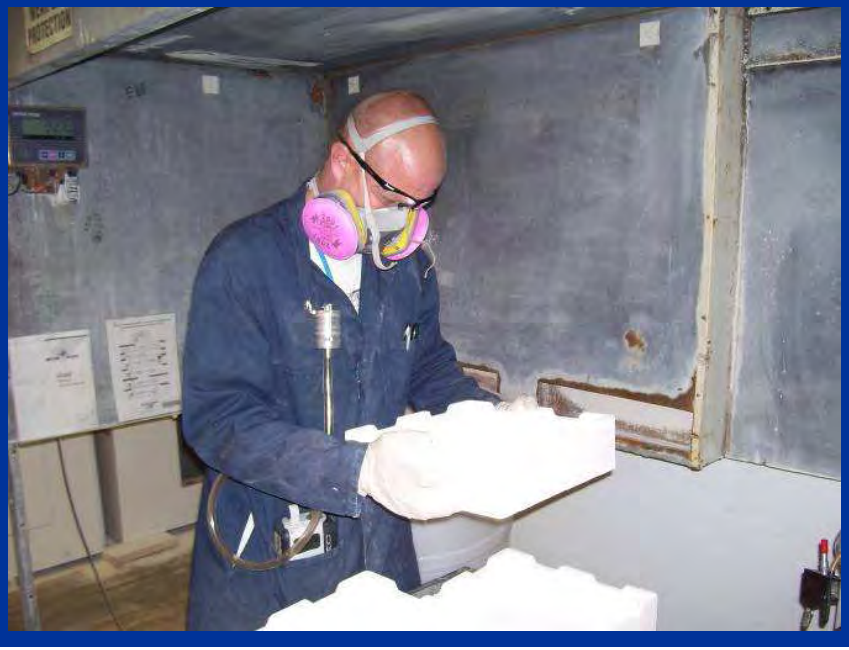
We have seen a range of tasks and 'controls' in research, development, and production





Controls for Lab-Scale Work

Effective controls that factor budget and space limitations are available

Select controls based on task-based exposure risks

Keeping laboratory bench tops clear facilitates cleaning

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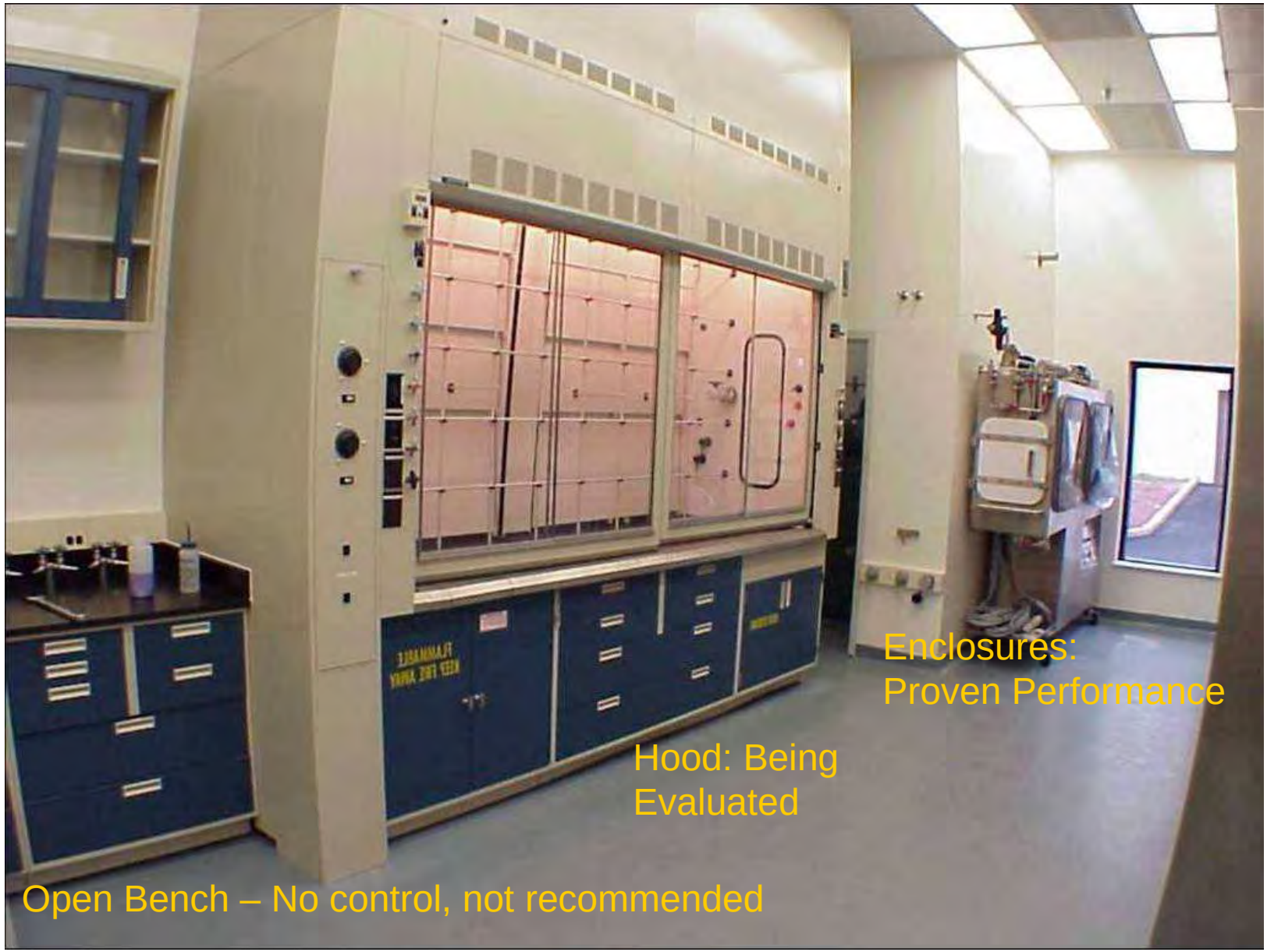
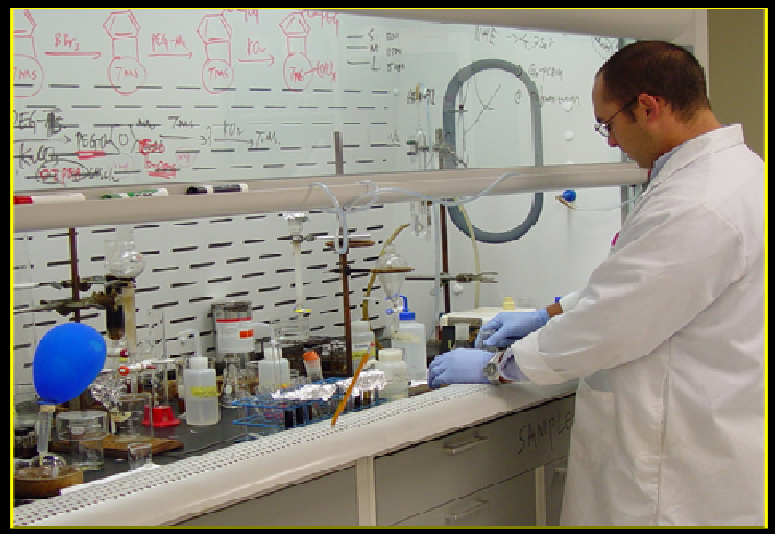
Multipurpose laboratory example with a range of controls



Fullerene preparation for medical applications

A. HARVESTING SOOT

B. SEPARATIONS

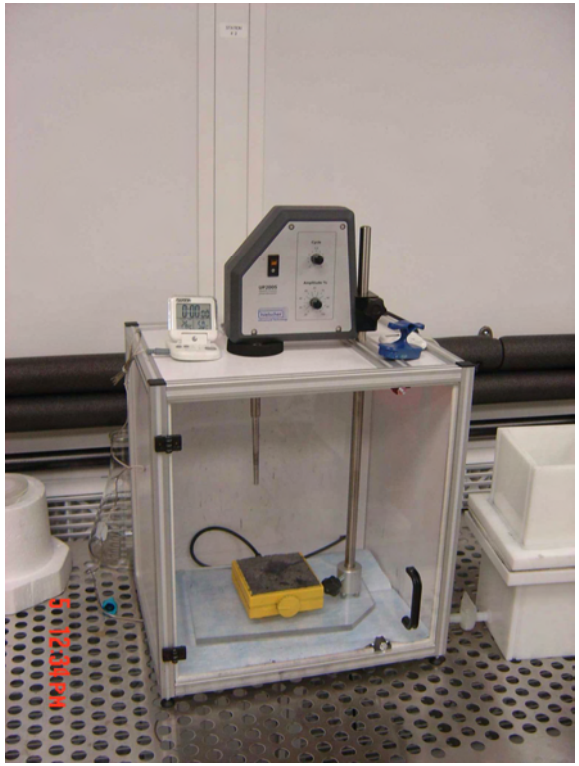


C. PURIFICATION

D. FUNCTIONALIZATION

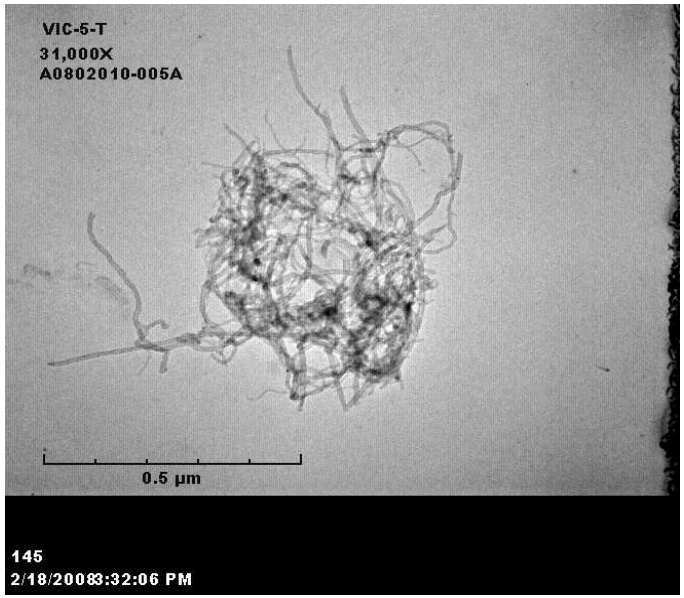
Photos from Luna Innovations

Small Tasks



Sonicator: enclosure for noise and splash protection and placed on a **ventilated bench top** (100 fpm).

Earlier measurements for a similar task before controls revealed airborne CNT bundles. None detected after control.

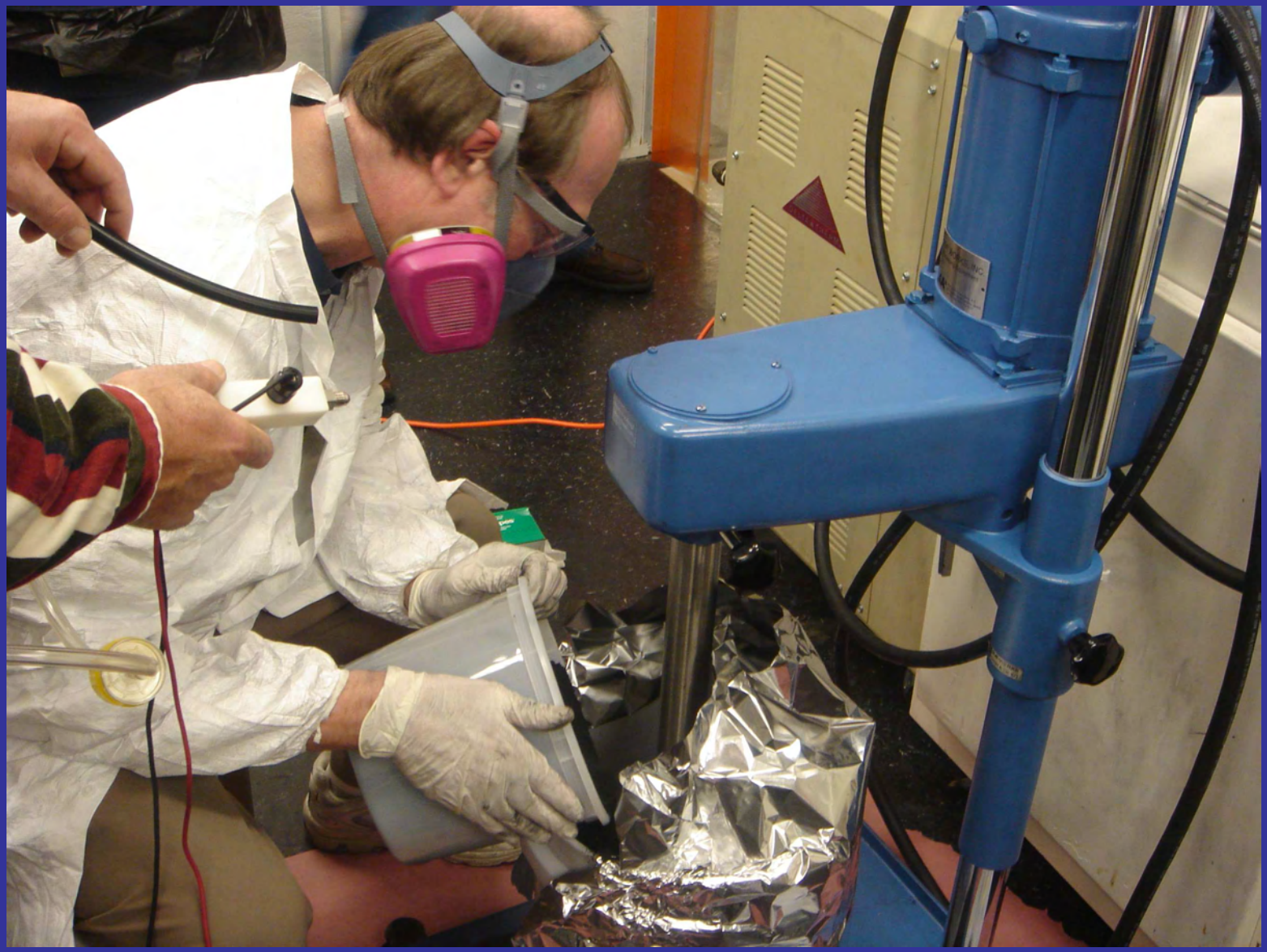


MWCNT's Collected During Sonication without controls in place

General Room ventilation plus PPE
– not the best approach

Solution: Ventilated Balance Safety Enclosure®

Mixing carbon nanofibers into a resin



Batches could come prepackaged in closed mixing containers for production work.

Small Task – Basic Control

Ventilated enclosure used to control potential emissions during destructive testing of electrospun nanofiber on a cellulose substrate

Particle counts used to measure possible releases during testing. Counts outside enclosure were not significantly above background.

Batch mixing: simple controls do help

Local exhaust ventilation controlling fugitive emissions during precursor mixing at a primary nanoscale metal oxide production facility.

Mixing a highly agglomerated form of a metal oxide; primary particle size ranges from 50 to 200 nm. The particle size detected before the simple control ranged from 5 to 50 um.

Preparing a suspension of metal oxide powder for production of nano metal oxide

Drum removal from a bag house

Measuring emissions at an ‘open point’

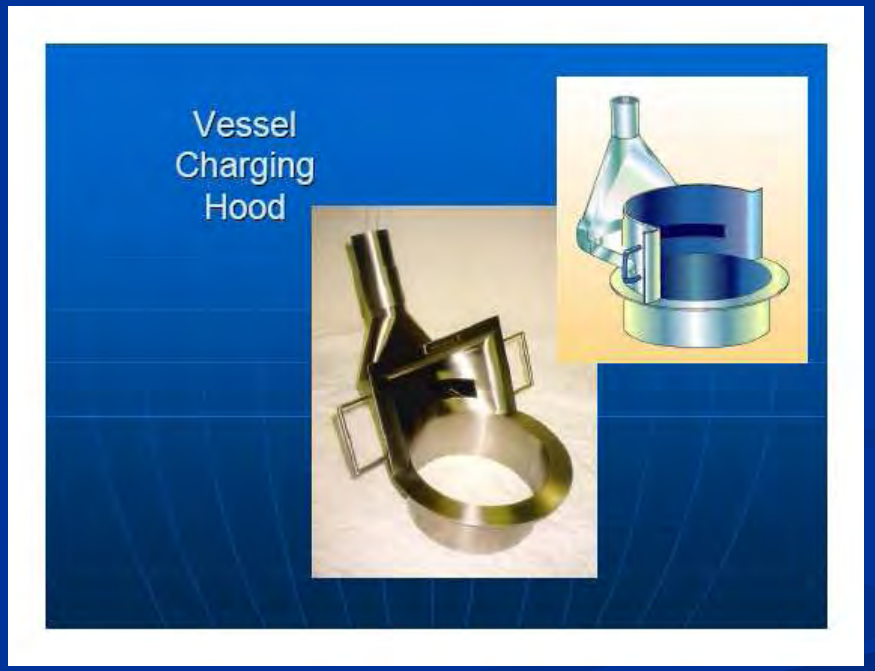
Larger Scale: Controlled Approach

Mixing of CNF's inside ventilated enclosure (face of opening is covered in plastic strips for easy access). Air is drawn underneath plastic strips and up to ceiling exhaust vents.

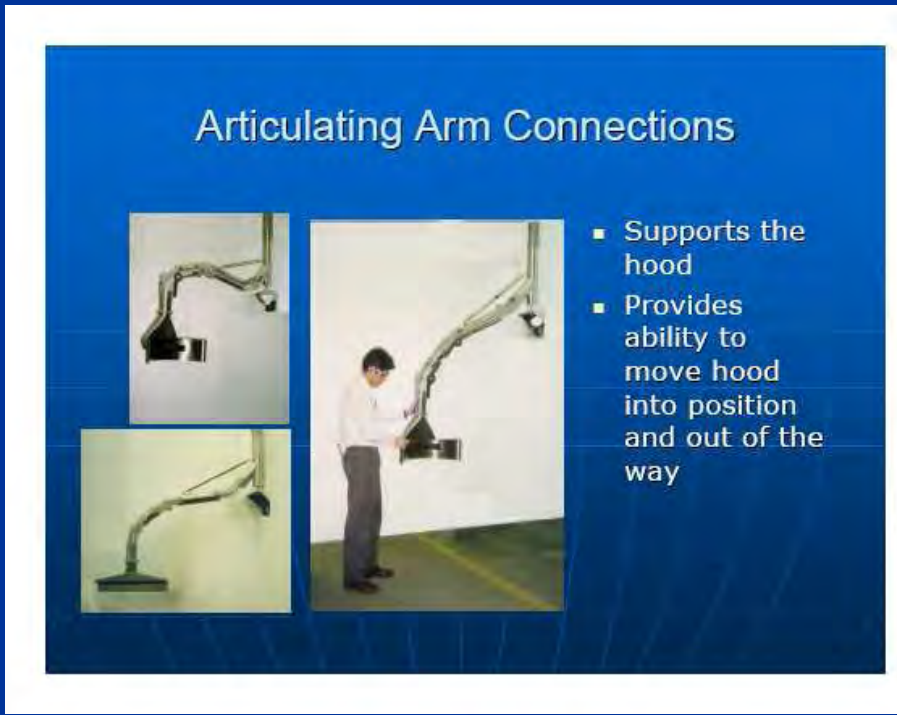
Larger Scale: Flexible control

Articulating ventilation unit used near exhaust outlet of oven when drying CNF slurry

Reapplication Opportunities



Reapplication Opportunities



Reapplication Opportunities

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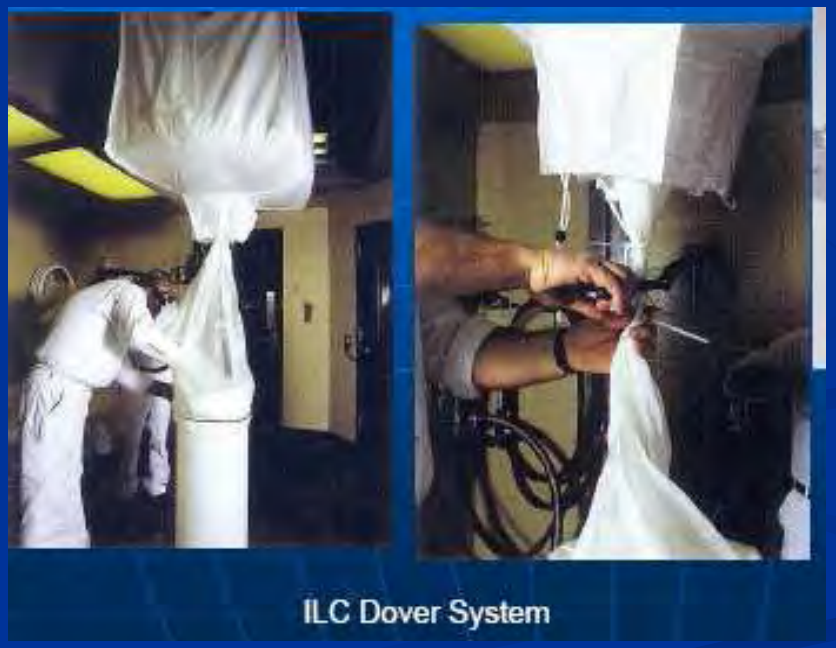
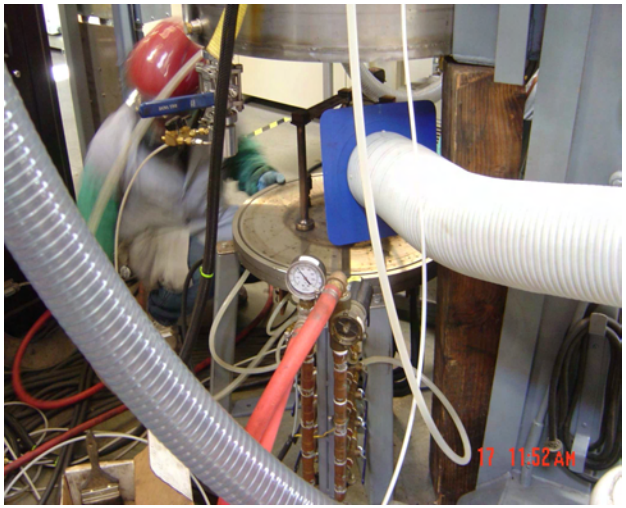


ILC Dover System

Use of LEV during plasma reactor cleanout: Stick around for the workshop!



Conclusions and State of Knowledge

- Nanotechnology offers the opportunity for effective Risk Management from synthesis to production.
- Many control strategies developed for ultrafine particles and fine particles can be reapplied.
- Each situation should be evaluated to match the control with the task.
- Gaps need to be identified as the technology continues to expand.

The Nanotechnology Field Research Team Update

In 2006, NIOSH established a Nanotechnology Field Research Team to expand its knowledge and understanding of the potential health and safety risks that workers may encounter during the research, production, and use of engineered nanomaterials. This effort has complimented NIOSH's extensive laboratory-based research program, as well as helped NIOSH identify and more fully understand the variety of work processes used to generate and manufacture engineered nanomaterials. It has also provided NIOSH with the opportunity to observe and evaluate work practices and engineering controls used to ensure worker health and safety in the nanotechnology industry.

NIOSH has conducted site visits to several facilities around the country that are involved in the research, manufacture, or use of various types of nanomaterials including, metal and metal oxide nanoparticles, carbon nanofibers, electrospun nanofibers, quantum dots, fullerenes, and nanocomposites. As a result, NIOSH obtained valuable information that is being used to assist in developing workplace guidance documents to protect nanotechnology workers from occupational injury and illness, and has learned that:

- basic particle counting and sizing instruments can be used to identify emissions from nanomaterial processes,
- careful interpretation of the particle data is needed to differentiate between incidental (background) and process-related nanoparticles, and
- engineering controls do minimize workplace exposure to engineered nanoparticles.

Companies interested in receiving a visit by the Field Research Team are encouraged to contact NIOSH. All site visits are initiated by the respective companies and are completely voluntary. This program is fully funded by NIOSH; therefore, there is no monetary cost to the participant. Three companies who have voluntarily received site evaluations from the NIOSH Field Research Team were recently interviewed by Nanowerk, LLC for its August/September 2007 issue of Nanorisk (www.nanorisk.org/). Overall, they described the collaboration as beneficial, and encouraged other companies to take advantage of NIOSH's expertise, services, instrumentation, and unbiased assessments.

For more information about occupational safety and health topics pertaining to engineered nanomaterials, including fact sheets about the Field Research effort and other nanotechnology research programs, please visit the NIOSH nanotechnology topic page at www.cdc.gov/niosh/topics/nanotech. To discuss the possibility of receiving a site evaluation by the NIOSH Field Research Team, contact Charles Geraci, Ph.D., CIH at (513) 533–8339, CGeraci@cdc.gov or Mark Methner, Ph.D., CIH at (513) 841–4325, MMethner@cdc.gov.

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH

Collaboration

- Share knowledge
- Use expertise
- Build experience
- Partner

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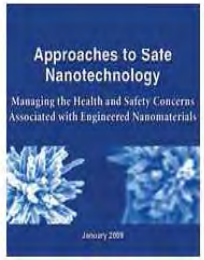
Nanotechnology at NIOSH

NIOSH is the leading federal agency conducting research and providing guidance on the occupational safety and health implications and applications of nanotechnology. This research focuses NIOSH's scientific expertise, and its efforts, on answering the questions that are essential to understanding these implications and applications:

- How might workers be exposed to nano-sized particles in the manufacturing or industrial use of nanomaterials?
- How do nanoparticles interact with the body's systems?
- What effects might nanoparticles have on the body's systems?



NIOSH Nanotechnology Topic Page
http://www.cdc.gov/niosh/topics/nanotech/

On this page....

NIOSH Publications

Approaches to Safe Nanotechnolog: Managing the Health and Safety Concerns Associated with Engineered Nanaomaterials (Prepublication Copy)
DHHS (NIOSH) Publication No. 2009-XXX
This document reviews what is currently known about nanoparticle toxicity, process emissions and exposure assessment, engineering controls, and personal protective equipment. This updated version of the document incorporates some of the latest results of NIOSH research, but it is only a starting point. The document serves a dual purpose: it is a summery of NIOSH's current thinking and interim recommendations; and it is a request from NIOSH to occupational safety and health practitioners, researchers, product innovators and manufacturers, employers, workers, interest group members, and the general public to exchange information that will ensure that no worker suffers material impairment of safety or health as nanotechnology develops.

NIOSH Current Intelligence Bulletin (CIB) Interm Guidance for Medical Screening and Hazard Surveillance for Workers Potentially Exposed to Engineered Nanoparticles (Prepublication Copy)
DHHS (NIOSH) Publication No. 2009-116
This document provides interim guidance from NIOSH concerning hazard surveillance and specific medical screening of asymptomatic workers.Such screening would be beyond any medical surveillance already occurring as part of existing occupational health surveillance.

The Nanotechnology Field Research Team Update
DHHS (NIOSH) Publication No. 2008-120
This document is an update of the NIOSH Nanotechnology Field Research team's efforts to evaluate work practices and engineering controls used to ensure worker safety and health in the nanotechnology industry. The update includes comments from participating companies interviewed by Nanowerk, LLC who described the collaboration as beneficial and encouraged other companies to take advantage of NIOSH's expertise, service, instrumentation, and unbiased assessments.

NIOSH Fact Sheet: The Nanotechnology Field Research Effort
DHHS(NIOSH) Publication No. 2008-121
A description and call for participants for the NIOSH Nanotechnology Field Research team's efforts to evaluate work practices and engineering controls used to ensure worker health and safety in the nanotechnology industry.

Safe Nanotechnology in the Workplace
DHHS (NIOSH) Publication No. 2008-112
This brochure provides an introduction to nanotechnology in the workplace for employers, managers, and safety and health professionals. It addresses the following questions: Are nanoparticles hazardous to workers? How can workers be exposed? Can nanoparticles be

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start | Approaches to Safe ... | 10:32 PM

Your NIOSH Nanotechnology CD

Good Nano Guide Wiki

- Protected Internet site on occupational practices for the safe handling of nanomaterials
- Multiple stakeholders contribute, share and discuss information
- Modern, interactive, up-to-date

http://icon.rice.edu/projects.cfm?doc_id=12207

There is still work to be done.

NIOSH

Thank you!

Charles.Geraci@cdc.hhs.gov

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